Net primary productivity of macrophytes after five growing seasons in experimental planted and unplanted marshes

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Introduction

While the idea of compensatory mitigation can be a good one, its use in the regulatory process has been the subject of much concern (Kiraly et al., 1991). In the past, the success of a mitigation project was based upon establishment of wetland structure, mainly wetland hydrology and wetland vegetation (Erwin, 1989; National Research Council, 1992). Successful vegetation establishment is often used to support the feasibility of wetland creation and its role in mitigation (Race and Christie, 1982; Kruczynski, 1989). With the establishment of wetland hydrology and vegetation, wetland functions are thought to be created.

One of those wetland functions is the net primary productivity (NPP) of a wetland macrophyte community. Productivity indicates the general health of the wetland community and its trophic status. NPP allows increases in biomass that can be utilized by heterotrophic consumers. The assessment of the vegetation in a newly created wetland through the measurement of NPP—and not only the estimation of plant structure such as diversity and cover—provide essential data on the functional capacity of a site.

Direct measurements of primary productivity were first made at the experimental wetland basins at the Olentangy River Wetland Research Park (ORWRP) in 1997. This study in 1998 represents the second set of such measurements. Before 1997 (the fourth growing season), harvesting was not considered a good option when vegetation was just getting started in the basins. By the fourth year, we determined that limited harvesting of plants to estimate the productivity of the system was possible without affecting the trajectory of the overall system.

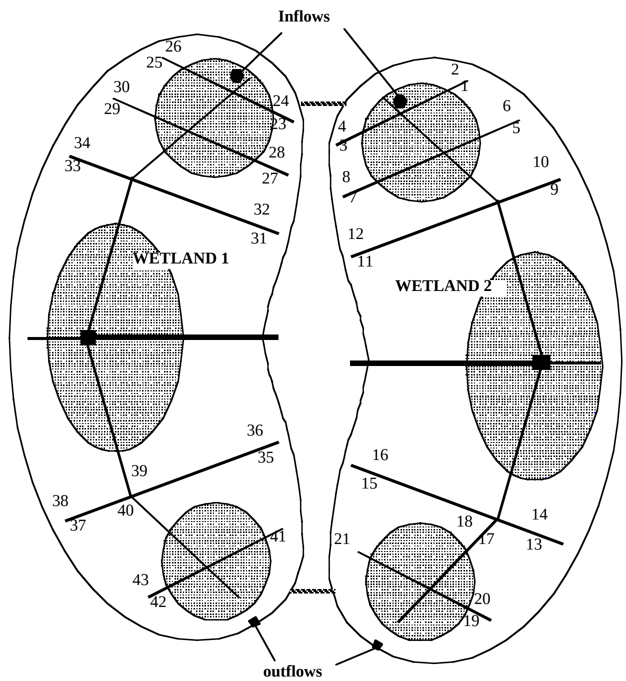

Figure 1. Sampling stations used for macrophyte harvesting, August 1998.

Methods

Net aerial primary productivity (NAPP) was estimated by harvesting peak biomass at the end of the growing season (end of August 1998) at selected stations in the two experimental wetland basins at the ORWRP (Fig. 1). The same stations established from the boardwalk system in 1997 (Mitsch and Bouchard, 1998) were visited again in 1998. To avoid harvesting the exact same spots, quadrats were 2 m—and not 1 m—from the outer edge of boardwalk in 1998 and were 1 m from the edge of the boardwalk. In each station, we used a 1-m^2 quadrat to delimitate the area of vegetation for harvest. When no vegetation was present, the station was skipped. Overall, we used 21 stations in each wetland. However, in each basin, 4 of these 21 stations were not colonized by macrophytes. As a result, 16 quadrats were sampled in each wetland, 8 in the northern or inflow half of the basins and 8 in the southern or outflow half of the basins. In each quadrat, plants were clipped at ground level (water was lowered in the wetlands to make sampling easier and to allow rapid recovery of the clipped plants). Samples were segregated both by quadrat and by species, placed in plastic bags and weighed in the field with a hanging balance (accuracy to 40 g). Sub-samples were taken to the laboratory where both wet weight (WW) and dry weight (DW, dried at 105°C for 48 hours) were determined to estimate dry/wet ratios. Ratios were multiplied by total wet weight of each species at each quadrat to estimate total dry weight production. The sum of all species in a quadrat was the estimated peak biomass and hence annual above-ground productivity.

Results and Discussion

Comparison of basins and location

In 1998, NAPP was estimated to be 729±55 g/m^2-yr in Wetland 1 and 1127±64 g/m^2-yr in Wetland 2 for the areas covered by macrophytes (Table 1). The productivity in Wetland 2 was significantly higher than the productivity of Wetland 1 (t-test, n=16, α=0.05). Between 1997 and 1998, the productivity of Wetland 2 significantly increased (t-test, n=16, α=0.05) while the productivity remained stable in Wetland 1 (t-test, n=16, α=0.05) (Figure 2).

In 1998, the productivity was significantly higher near the inflow (1282 ± 64 g/m^2-yr) than the outflow (972 ± 81 g/m^2-yr) in the unplanted Wetland 2 (t-test, n = 8, α=0.05). Productivity followed the same pattern in Wetland 1 (850 ± 63 at the inflow vs. 608 ± 70 g/m^2-yr at the outflow) but this differences was not significant (t-test, n = 8, α=0.05). Comparing the two basins, productivity was higher in Wetland 2 for both the inflow samples (t-test, n = 8, α=0.05) and the outflow samples (t-test, n = 8, α=0.05).

Dry/wet ratios

For future reference, the dry/wet ratios of individual plants at the ORW might prove useful (Table 2; complete data are shown in Appendices A and B). Ratios ranged from about 30% dry/wet ratios for *Schoenoplectus* to about 10% ratios for *Sagittaria*.

Table 1. Estimated net above-ground primary productivity (NAPP) of macrophyte communities in Olentangy River experimental wetlands, August 1998, based on peak biomass harvest. Numbers are ave±std error [# samples].

	Total NAPP (g/m^2-yr)	Inflow NAPP (g/m^2-yr)	Outflow NAPP (g/m^2-yr)
Wetland 1	729±55 [16]	850±63 [8]	608±70 [8]
Wetland 2	1127±464 [16]	1282±64 [8]	972±81 [8]

Table 2. Dry/wet ratios (ave±std error (# samples)) of dominant macrophytes in Olentangy River wetlands in 1998.

Species	Wetland 1	Wetland 2
S. tabernaemontani	0.311±0.005 (14)	0.304±0.004 (16)
S. fluviatilis	0.276±0.003 (4)	
S. latifolia	0.106±0.010 (4)	
S. eurycarpum	0.211±0.004 (9)	
Typha spp.	0.230±0.005 (5)	0.241±0.004 (15)

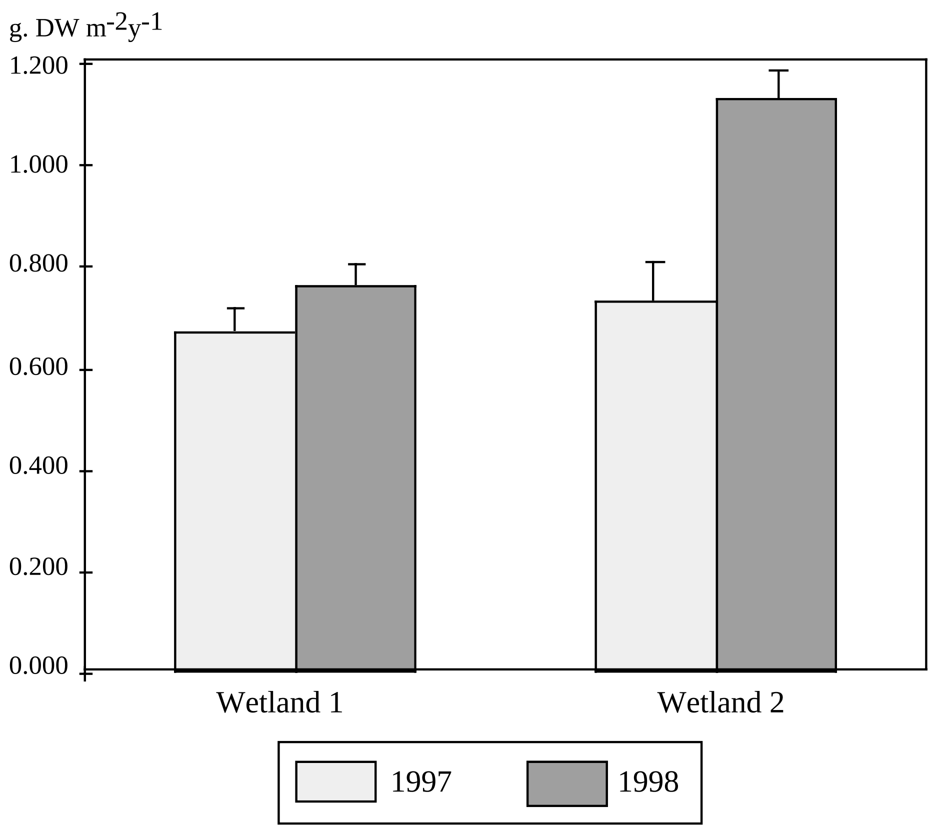

Figure 2. Net Aerial Primary Production in Wetland 1 and 2 in 1997 (Mitsch and Bouchard, 1998) and 1998 (this study)

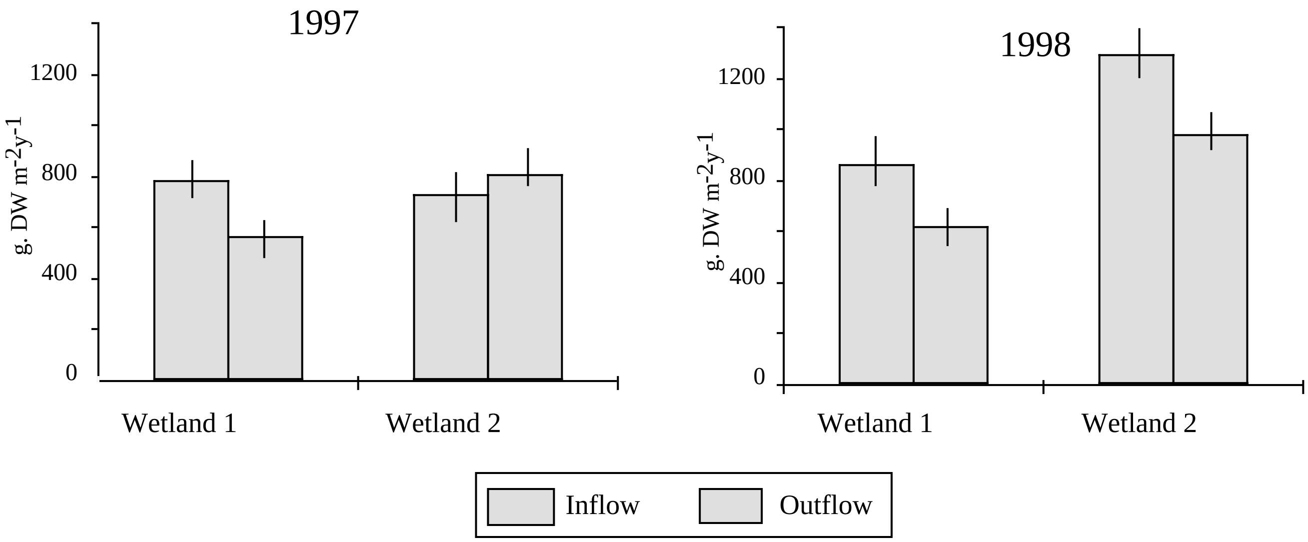

Figure 3. Net Aerial Primary Production at the inflow and outflow of both wetlands in 1997 (Mitsch and Bouchard, 1998) and 1998 (this study)

Species dominating the productivity

The species harvested in the two basins indicate differences that still linger from the planting experiment of 1994 (Fig. 4). Wetland 1, which was planted with 12 species in May 1994, had 5 taxa found in the quadrats that contributed to the above-ground productivity. Four of these taxa (*Schoenoplectus tabernaemontani*, *Sparganium eurycarpum*, *Scirpus fluviatilis* and *Sagittaria latifolia*) were planted in 1994 and these taxa represented 90% of the macrophyte above-ground productivity in the harvested quadrats. Of these four, *Schoenoplectus tabernaemontani* was dominant (62%), with much lower contribution by *Sparganium* (17%) and by *S. fluviatilis* (10%), and minimal contribution by *Sagittaria* (less than 1%). Colonizing *Typha* provided the remaining 10% of the above-ground productivity. *Typha* contribution to the wetland NAPP was higher in 1997 with 14% (Mitsch and Bouchard, 1998). As a matter of fact, *Typha* was only found in 5 quadrats (Table 2) while the species was found in 7 quadrats in 1997 (Mitsch and Bouchard, 1998). The opposite pattern appeared with *Sparganium* whose contribution to the wetland NAPP increased between 1997 and 1998. This species was found in 7 quadrats in 1997 (Mitsch and Bouchard, 1998) and in 9 quadrats in 1998.

Only two taxa (*Typha* spp. and *Schoenoplectus tabernaemontani)* contributed to the productivity in Wetland 2 and, of course, both were colonizers. Between 1997 and 1998, we observed a rapid increase of *Typha* production. In 1997, *Typha* spp. contributed 15% of the NAPP; in 1998, *Typha* spp. contributed up to 48% of the production. In 1997, *Schoenoplectus* was significantly more productive than *Typha* (t-test, n = 8, α=0.05); that difference of production was not significative in 1998 (t-test, n = 8, α=0.05).

If we consider the percent cover of the two dominant species (*Schoenoplectus tabernaemontani* and *Typha* spp.) in each wetland (Bouchard et al., 1999), the respective contribution of these species changed. *Typha* spp. produced an estimated 6 kg dry weight (DW) and 1670 kg DW in Wetlands 1 and 2 respectively, and *Schoenoplectus tabernaemontani* produces 1389 kg DW and 1113 kg DW in Wetland 1 and 2 respectively. Compared to 1997 estimation (Mitsch and Bouchard, 1998), these numbers indicate the fast progression of *Typha* in Wetland 2 and its regression in Wetland 1 during the fifth growing season of these experimental basins. According to these estimations, at the basin level, 90% of the biomass was produced by *Schoenoplectus tabernaemontani* in Wetland 1 and less than 1% was produced by *Typha* spp. In Wetland 2, *Schoenoplectus tabernaemontani* and *Typha* spp. produced 40% and 60 % of the total NAPP respectively. However these estimates might suffered of an incorrect sampling design; the sampling design was originally decided in 1997 (and then followed again for this study) to estimate the global production of each basin, and not to estimate each community production.

Autochthonous carbon sources from macrophytes

Based on the above-ground productivity estimates and the aerial estimates of vegetation cover presented elsewhere in this annual report (Bouchard and Mitsch, 1999), above-ground productivity by macrophytes is an estimated 3319 kg and 5611 kg in Wetland 1 and Wetland 2, respectively. [This is calculated as the overall NAPP in Table 1 in this chapter times the “vegetation cover” in Table 2 in Bouchard and Mitsch, 1999]. This production is higher than the one estimated in 1997: 2525 kg and 3130 kg in Wetland 1 and

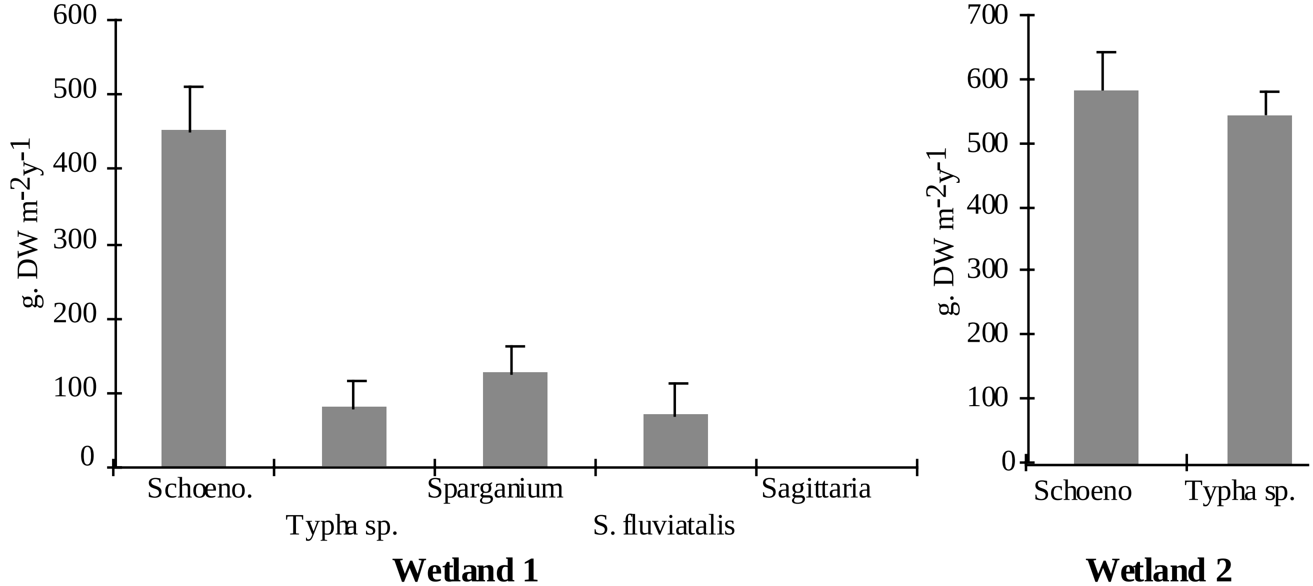

Figure 4. Distribution of peak biomass in August 1998 in two experimental wetland basins. Four of the five species listed in Wetland 1 were planted in May 1994.

Wetland 2, respectively (slight correction in W2 number from Mitsch and Bouchard, 1998). Assuming that above-ground productivity represents half of the above-ground plus below-ground plant productivity and that gross primary productivity (GPP) represents twice NPP (and assuming that 1 g dry wt = 0.5 g C), the macrophyte communities were fixing an estimated 6,600 to 11,000 kg C/yr in Wetlands 1 and 2, respectively in 1998, compared to 5,000 to 6,000 kg C/yr in Wetlands 1 and 2 in 1997 (Mitsch and Bouchard, 1998). Wetland 1 gross carbon sequestration by macrophytes increased by 32% in one year while Wetland 2 carbon sequestration almost doubled (83% increase) in the same year.

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Appendix A. Harvested wet weight of plants in ORW experimental wetlands, August 1998. Station locations are shown in Figure 1.

Station #/Wet	S. validus	Typha sp.	Sparganium	S. fluviatalis	Sagittaria	Total
Wetland 2						
1	0.344	0.898	0.000	0.000	0.000	1.242
2	0.196	1.294	0.000	0.000	0.000	1.490
3	1.074	0.377	0.000	0.000	0.000	1.452
4	0.674	0.686	0.000	0.000	0.000	1.361
5	x	x	x	x	x	x
6	0.900	0.229	0.000	0.000	0.000	1.130
7	x	x	x	x	x	x
8	0.862	0.254	0.000	0.000	0.000	1.116
9	0.818	0.199	0.000	0.000	0.000	1.017
10	x	x	x	x	x	x
11	0.290	1.163	0.000	0.000	0.000	1.452
12	x	x	x	x	x	x
13	x	x	x	x	x	x
14	0.284	0.748	0.000	0.000	0.000	1.033
15	0.726	0.431	0.000	0.000	0.000	1.157
16	0.840	0.477	0.000	0.000	0.000	1.318
17	0.496	0.521	0.000	0.000	0.000	1.017
18	0.584	0.472	0.000	0.000	0.000	1.056
19	0.569	0.069	0.000	0.000	0.000	0.638
20	0.221	0.463	0.000	0.000	0.000	0.683
21	0.462	0.413	0.000	0.000	0.000	0.874
TOTAL	9.3	8.7	0.0	0.0	0.0	18.036
AVERAGE	0.584	0.543	0.000	0.000	0.000	1.127
# OBSERV	16	16	16	16	16	16
Wetland 1						
23	0.5	0.0	2.7	0.0	0.05	3.3
24	0.0	0.0	1.2	1.6	0.00	2.8
25	1.7	0.0	1.2	0.2	0.00	3.1
26	0.9	0.8	0.0	1.5	0.00	3.3
27	x	x	x	x	x	x
28	3.3	0.0	0.2	0.0	0.05	3.5
29	x	x	x	x	x	x
30	3.1	0.0	0.5	0.0	0.00	3.6
31	1.5	0.9	0.0	0.0	0.14	2.4
32	x	x	x	x	x	x
33	0.5	2.0	0.0	0.7	0.00	3.2
34	x	x	x	x	x	x
35	1.7	0.6	0.0	0.0	0.0	2.4
36	2.4	1.3	0.0	0.0	0.1	3.8
37	0.0	0.0	1.9	0.0	0.0	1.9
38	x	x	x	x	x	x
39	1.8	0.0	0.0	0.0	0.0	1.8
40	1.5	0.0	0.0	0.0	0.0	1.5
41	0.5	0.0	1.6	0.0	0.0	2.2
42	2.1	0.0	0.3	0.0	0.0	2.4
43	1.5	0.0	0.1	0.0	0.0	1.6
TOTAL	23.1	5.5	9.8	4.1	0.3	42.8
AVERAGE	1.44	0.35	0.61	0.26	0.02	2.68
# OBSERV	16	16	17	16	16	16

Appendix B. Laboratory-measured dry/wet ratios from sub-samples for species harvested in experimental wetlands. *Scirpus* = *Schoenoplectus tabernaemontani*; *S. fluviatalis* = *Scirpus fluviatalis*; *Sagittaria* = *Sagittaria latifolia*; *Sparganium* = *Sparganium eurycarpum*. Sampling stations (Stations) shown in Figure 1.

Wetland 1

St #	Species	Wet wt, g	Dry wt, g	Dry/wet
24	*S. fluviatilis*	75.6	21.1	0.279
25	*S. fluviatilis*	62.3	17.6	0.283
26	*S. fluviatilis*	23.1	6.3	0.273
33	*S. fluviatilis*	52.3	14.2	0.272
23	*Sagittaria*	12.5	1.6	0.128
28	*Sagittaria*	23.2	2.3	0.099
31	*Sagittaria*	55.8	4.6	0.082
36	*Sagittaria*	44.2	5.0	0.113
23	*Scirpus*	62.3	19.6	0.315
25	*Scirpus*	87.5	28.6	0.327
26	*Scirpus*	32.2	10.3	0.320
28	*Scirpus*	40.2	12.3	0.306
30	*Scirpus*	42.1	14.2	0.337
31	*Scirpus*	38.9	11.2	0.288
33	*Scirpus*	23.6	7.4	0.314
35	*Scirpus*	28.1	7.6	0.270
36	*Scirpus*	63.2	19.2	0.304
39	*Scirpus*	38.5	11.5	0.299
40	*Scirpus*	12.1	4.1	0.339
41	*Scirpus*	31.2	9.3	0.298
42	*Scirpus*	32.1	10.2	0.318
43	*Scirpus*	32.1	10.3	0.321
23	*Sparganium*	60.2	12.3	0.204
24	*Sparganium*	62.3	12.9	0.207
25	*Sparganium*	54.2	11.1	0.205
28	*Sparganium*	50.2	10.8	0.215
30	*Sparganium*	63.2	12.3	0.195
37	*Sparganium*	56.3	11.3	0.201
41	*Sparganium*	41.2	9.6	0.233
42	*Sparganium*	29.6	6.3	0.213
43	*Sparganium*	23.3	5.2	0.223
26	*Typha*	123.2	28.4	0.231
31	*Typha*	86.3	20.3	0.235
33	*Typha*	56.3	12.3	0.218
35	*Typha*	39.6	9.8	0.247
36	*Typha*	74.6	16.3	0.218

Wetland 2

St #	Species	Wet wt, g	Dry wt, g	Dry/wet
1	*Scirpus*	69.8	19.6	0.281
2	*Scirpus*	56.3	18.7	0.332
3	*Scirpus*	58.4	18.2	0.312
4	*Scirpus*	26.3	8.5	0.323
6	*Scirpus*	54.2	16.3	0.301
8	*Scirpus*	101.2	29.6	0.292
9	*Scirpus*	63.2	21.1	0.334
11	*Scirpus*	38.6	11.2	0.290
14	*Scirpus*	74.1	21.1	0.285
15	*Scirpus*	26.3	8.1	0.308
16	*Scirpus*	56.3	16.3	0.290
17	*Scirpus*	21.3	6.3	0.296
18	*Scirpus*	58.9	18.5	0.314
19	*Scirpus*	51.2	15.3	0.299
20	*Scirpus*	53.6	16.3	0.304
21	*Scirpus*	42.1	12.6	0.299
1	*Typha*	29.6	6.3	0.213
2	*Typha*	63.2	14.2	0.225
3	*Typha*	56.8	13.5	0.238
4	*Typha*	89.4	19.6	0.219
6	*Typha*	74.1	16.3	0.220
8	*Typha*	78.5	19.1	0.243
9	*Typha*	63.2	14.6	0.231
11	*Typha*	98.5	23.6	0.240
14	*Typha*	78.4	19.9	0.254
15	*Typha*	78.3	20.1	0.257
16	*Typha*	56.3	14.1	0.250
17	*Typha*	98.6	23.1	0.234
18	*Typha*	74.2	19.8	0.267
19	*Typha*	65.2	14.2	0.218
20	*Typha*	85.6	21.3	0.249
21	*Typha*	79.6	21.3	0.268